



TDRSS Augmentation Service for Satellites (TASS)



SPACE COMMUNICATIONS AND NAVIGATION

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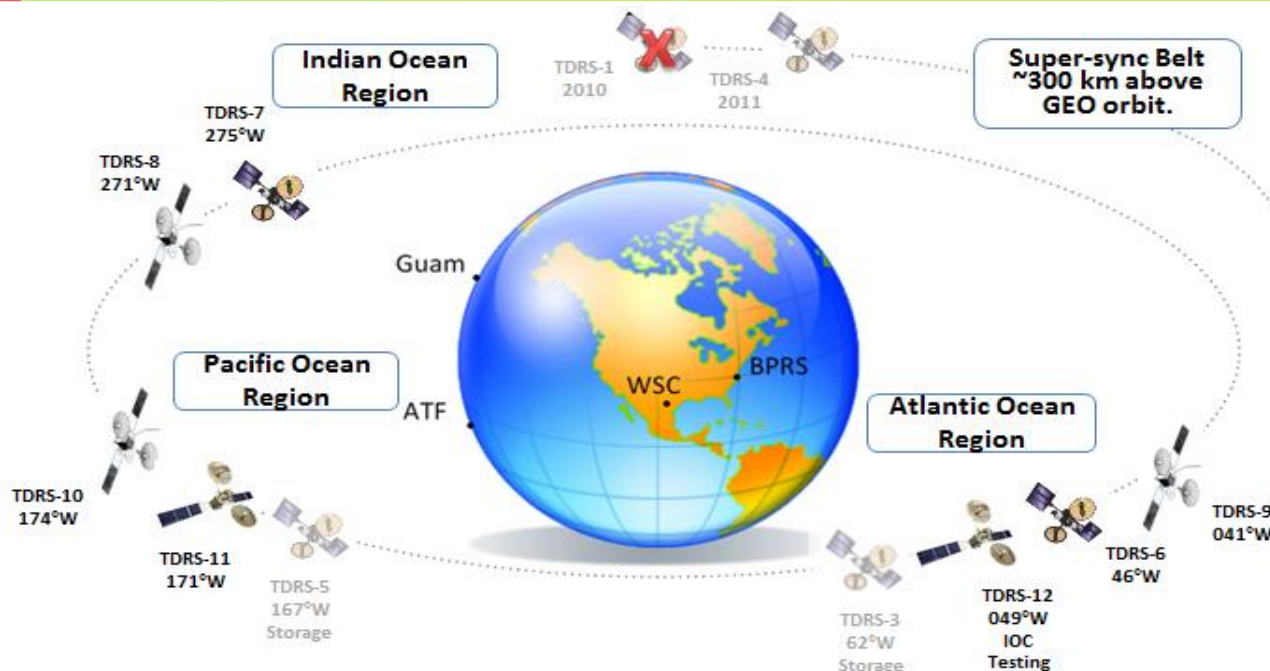
NASA Goddard Space Flight Center





NEXT GENERATION BROADCAST SERVICE (NGBS)

Objectives



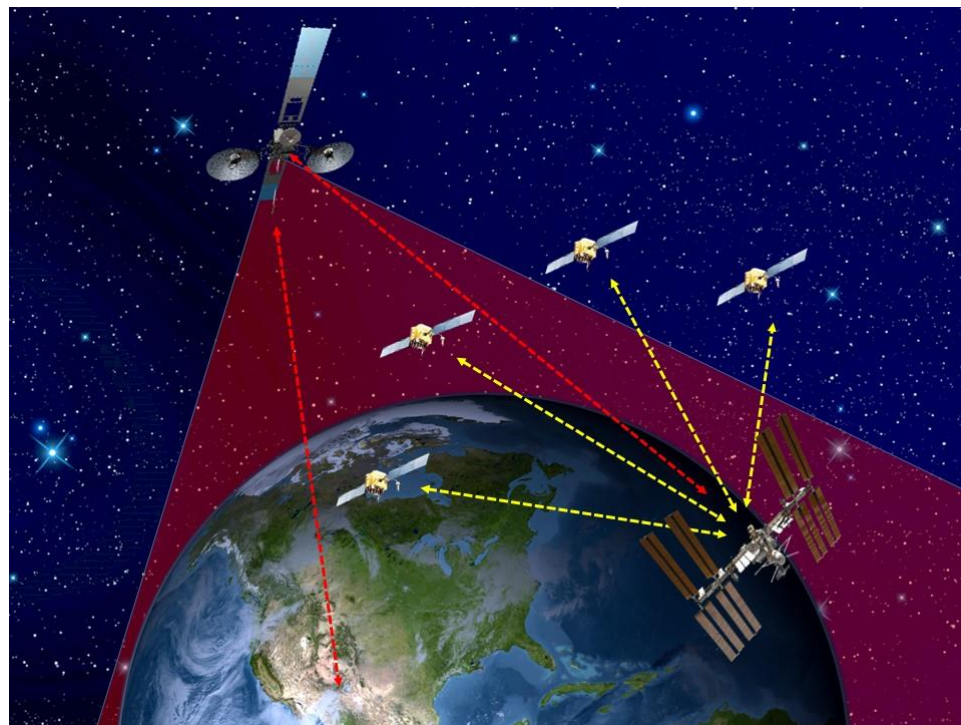
- Current: space communications achieved through the Near Earth Network (NEN) ground terminals and the Space Network (SN)
 - The SN is composed of the Tracking and Data Relay Satellites (TDRS)
 - Requires service scheduling by Mission Operations Centers (MOCs) days in advance
 - Few spacecraft perform autonomous, on-board navigation
- Improved, future network
 - Enables user-hailed services that are autonomously scheduled by the network
 - Provides spacecraft with radiometrics and data to support autonomous, on-board navigation
 - Expands service volume



Service Description



- NGBS provides unique signals and data to *enhance user operations and enable autonomous onboard navigation*
- NGBS service consists of:
 - Global coverage via TDRSS S-band multiple access forward (MAF) service
 - Unscheduled, on-demand user commanding
 - Space environment/weather: ionosphere, Kp index for drag, alerts, effects of Solar Flares/CMEs
 - Earth orientation parameters
 - TDRS ephemerides and maneuver windows
 - PN ranging code synchronized with GPS time for time transfer, one-way forward Doppler and ranging
 - Global differential GPS corrections
 - GPS integrity



NGBS has direct benefits in the following areas:

- Science/payload missions
- SCaN/Network operations
- TDRSS performance
- GPS and TDRSS onboard navigation users
- Conjunction Assessment Risk Analysis
- Capabilities consistent with the modern GNSS architecture



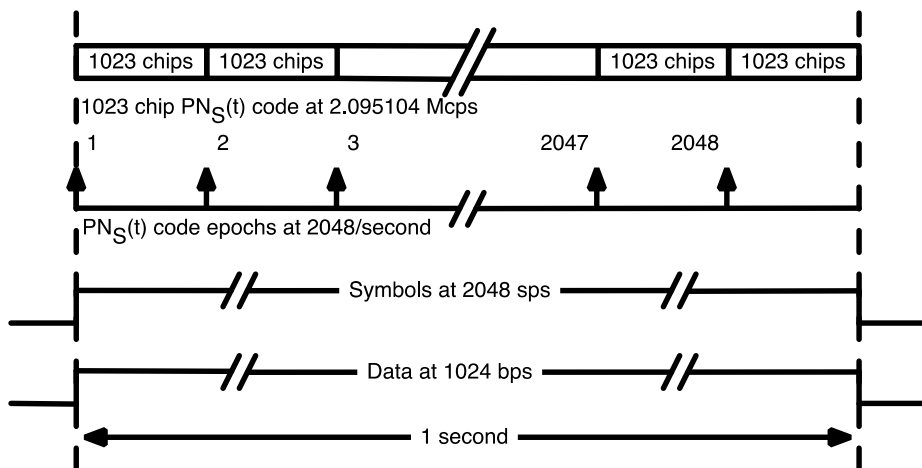
NGBS and the Space Mobile Network



- Proposed Space Mobile Network (SMN)
 - Similar to the architectural concepts that enable today's terrestrial wireless networks
 - Provides automated delivery of communication services and always available positioning and navigation capability
 - User-hailing paradigm:
 - Spacecraft ("users") autonomously request a communications link from the network
 - Network autonomously schedules comm. link, considering relative locations of user and network nodes
- NGBS support of user-hailing
 - Beacon concept allows access to any spacecraft within the service volume
 - Signal structure allows radiometrics (range and Doppler measurements)
 - TDRS Ephemerides and Maneuver Windows provide relay location and integrity
- Additional benefits of NGBS
 - Data to supplement and improve on-board navigation (e.g., EOPs, TEC, Kp index, DGPS)
 - Forward commanding
 - Space weather

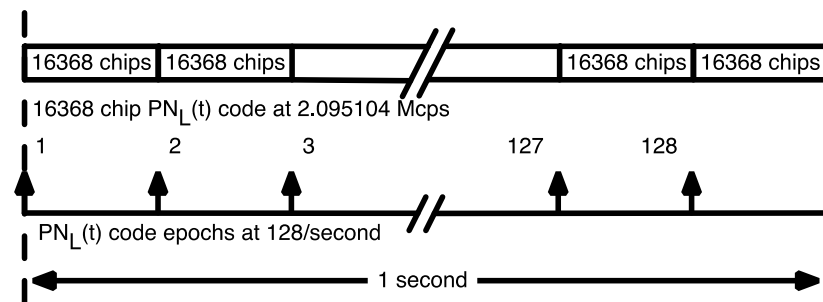
Signal Structure

Inphase Channel (Data)



- PN_S 1023 chips; PN_L 16368 chips
- 2048 PN_S sequences/second, 128 PN_L sequences/second
- 2.095104 Mcps (1023x2048) spreading rate
- Rational timebase, 2105.579520 MHz (1023x2048x1005) carrier frequency

Quadrature Channel (Pilot)



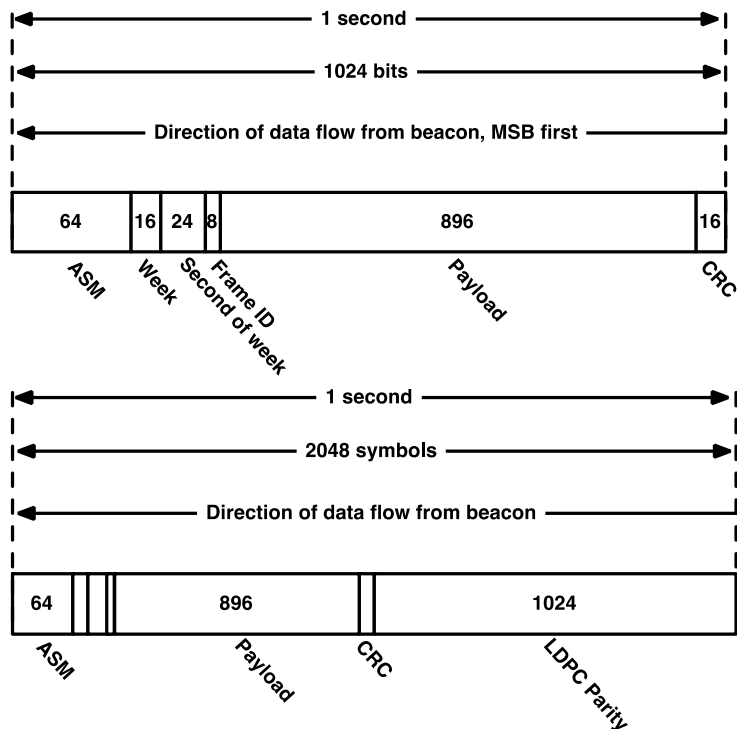
- 10:1 power ratio on I and Q channels (Q is a dataless pilot)
- 1024 bps, CCSDS LDPC (2048, 1024) rate $\frac{1}{2}$ encoded
- Designed for acquisition with zero a-priori information (lost in space)
- Designed for weak signal tracking



Data Message



Frame Structure



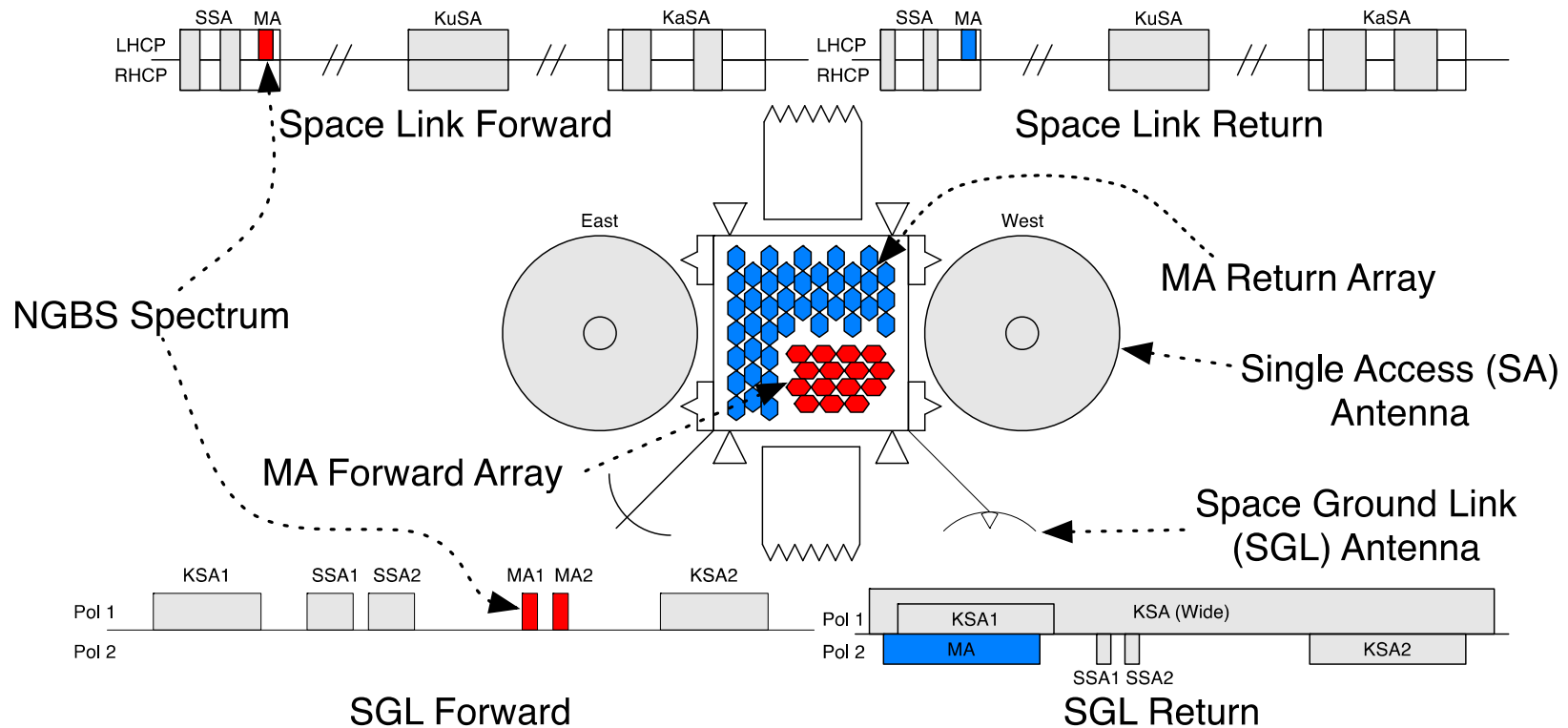
Data Message Allocations

Message	Label	Size (bits)	Quantity	Refresh Interval (s)	Data Volume
ASM	ASM	64	1	1	640
Week	WK	16	1	1	160
Second of Week	SOW	24	1	1	240
Frame ID	FID	8	1	1	80
GPS Integrity	A	184	10	10	1840
GPS Differential Corrections	B	72	32	10	2304
TDRS Ephemerides	C	200	10	10	2000
User Commands	D	200	4	10	800
Spares	E	200	4	10	800
Space Environment	F	152	3	10	456
Ionosphere	G	200	1	10	200
Solar flux	H	128	1	10	128
Earth Orientation	I	48	1	10	48
TDRS Health & Safety	J	200	1	10	184
Unused	U	200	1	10	200
CRC	CRC	16	1	1	160
				Totals	10240

- Data message in a framed structure, 10 seconds to broadcast entire message.
- ~80 bps on average allocated to user command. With spares & unused, 180 bps.
- Goal to achieve 2048 bps data rate. If achieved, 1024 bps will be allocated for user commands.



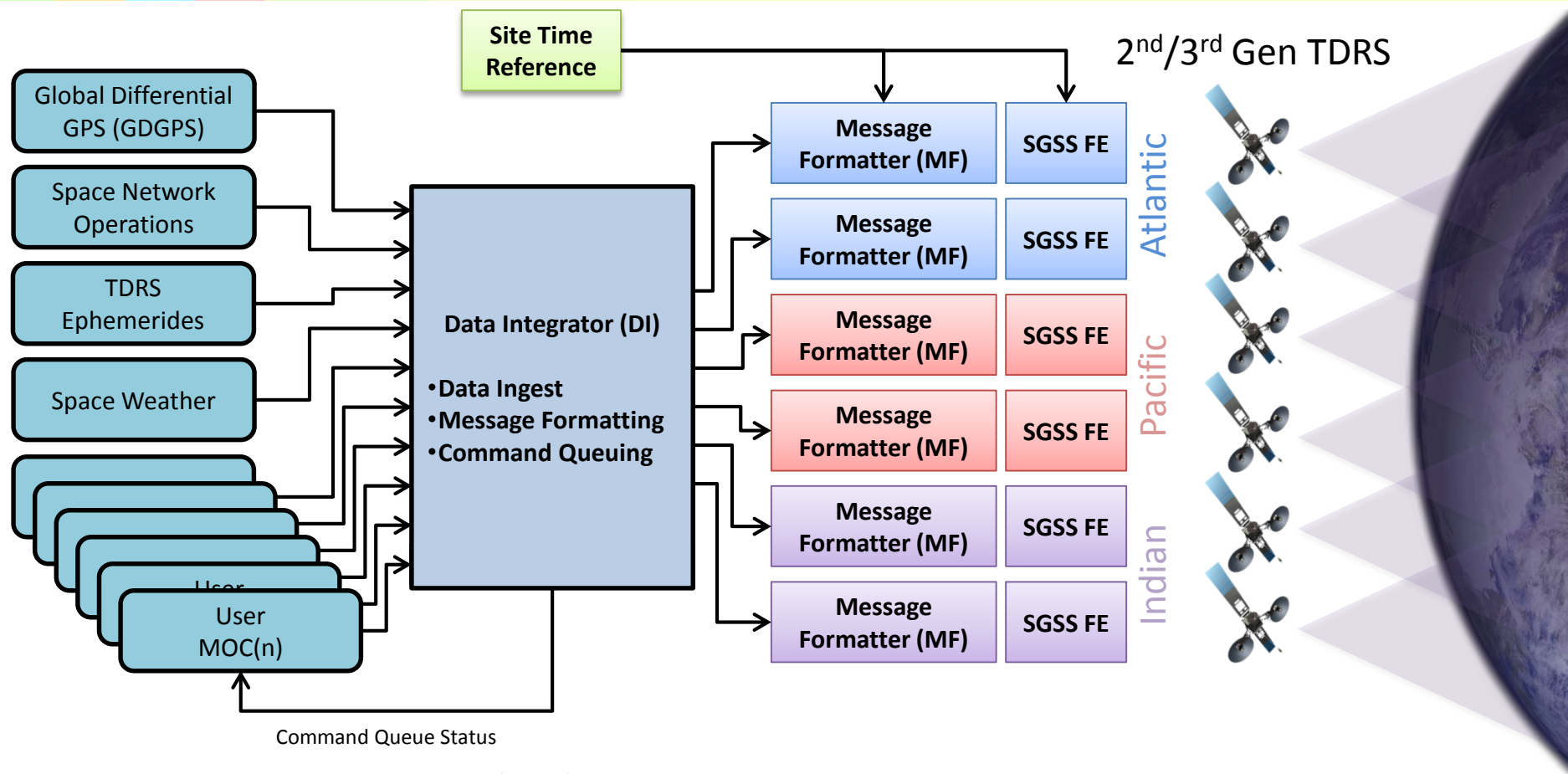
SYSTEM ARCHITECTURE



- 2nd/3rd gen TDRS used to broadcast NGBS beacon
- MA forward (MAF) array can be split to provide two simultaneous MAF services
 - Current Space Network ground system does not support this capability
- MA return (MAR) array supports Demand Access Service (DAS)
- In concert with DAS, NGBS will provide a unique anytime/anywhere two-way communications channel



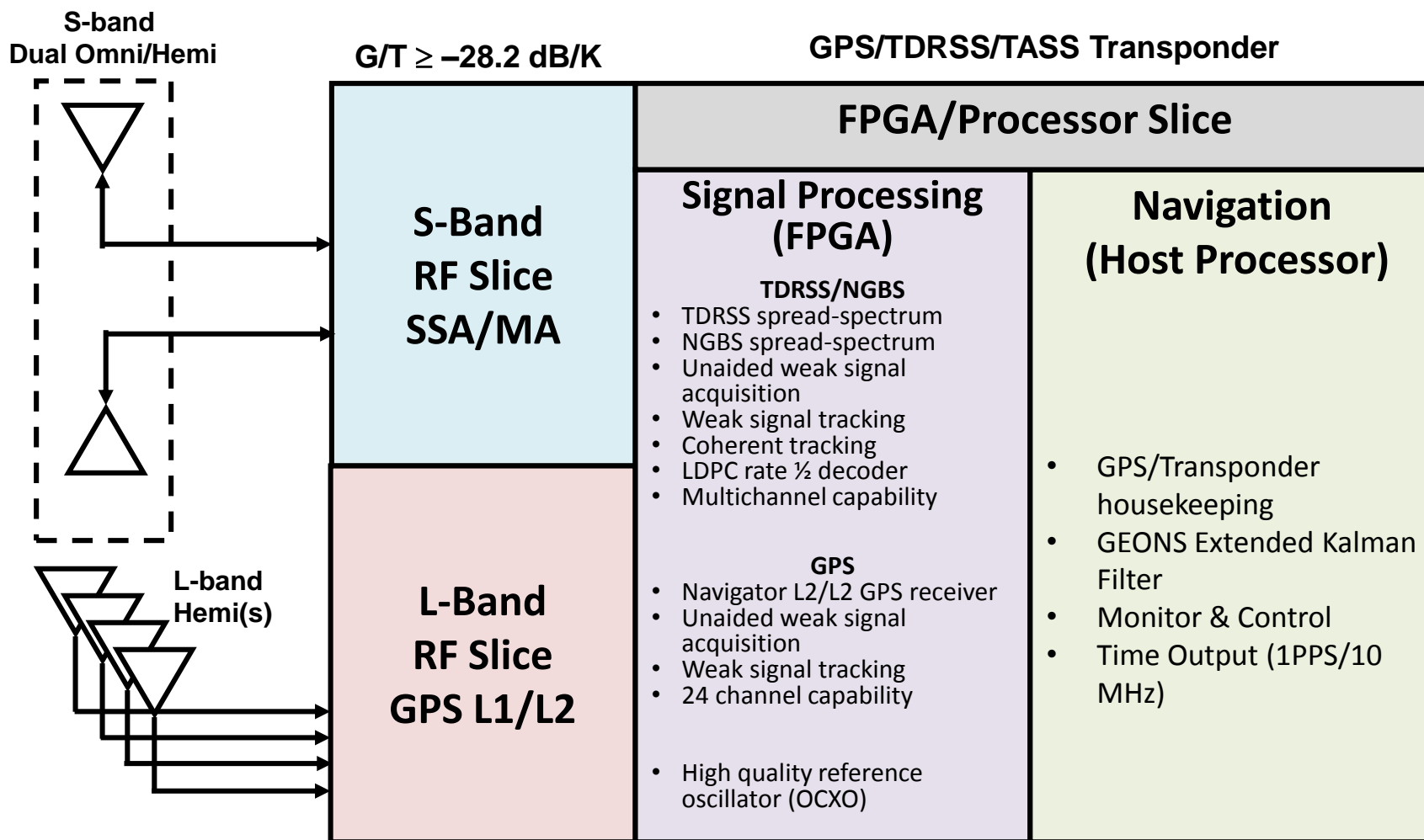
Ground Element



- Data Integrator (DI) located at WSC
- Message Formatters (MF) located in each NGBS enabled ground system



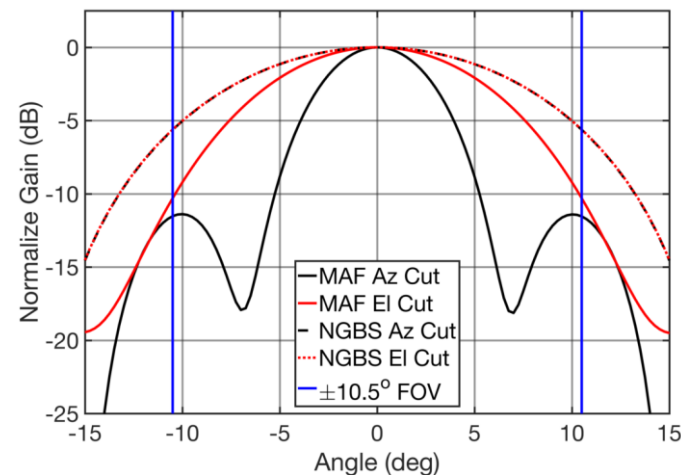
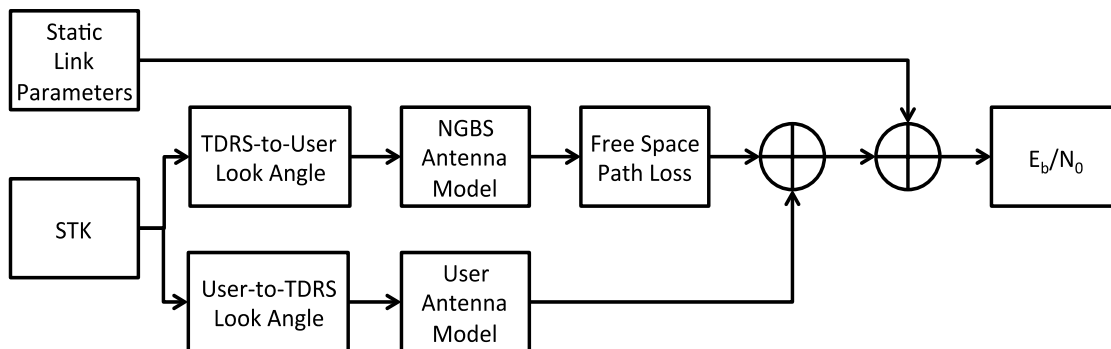
User Element



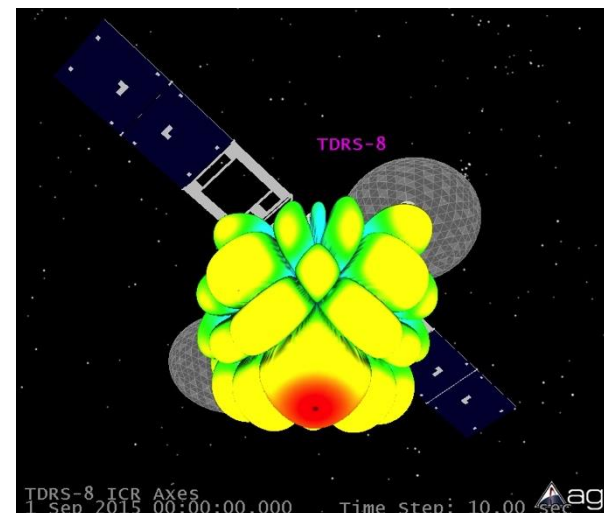


CURRENT STATUS

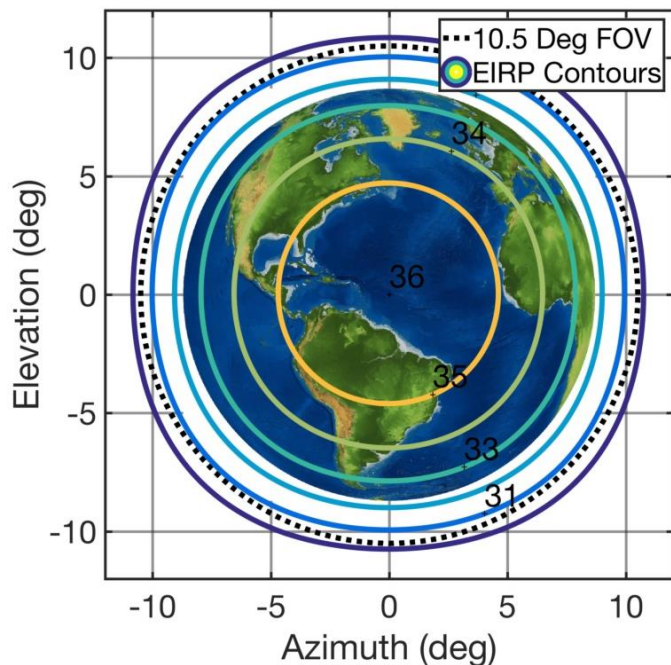
Simulation Parameter	Options
User Orbit	Low inc LEO, SSO LEO
User Antenna	-3 dB ISO, GPS, MMS, LADEE
MAF Configuration	4 Element
NGBS Constellation	3 nodes, 5 nodes



- Static link parameters combined with dynamic STK/MATLAB analysis
 - NGBS & user antenna models
 - Slant range
- Analyzed all combinations of NGBS constellation, user orbit, and user antenna models

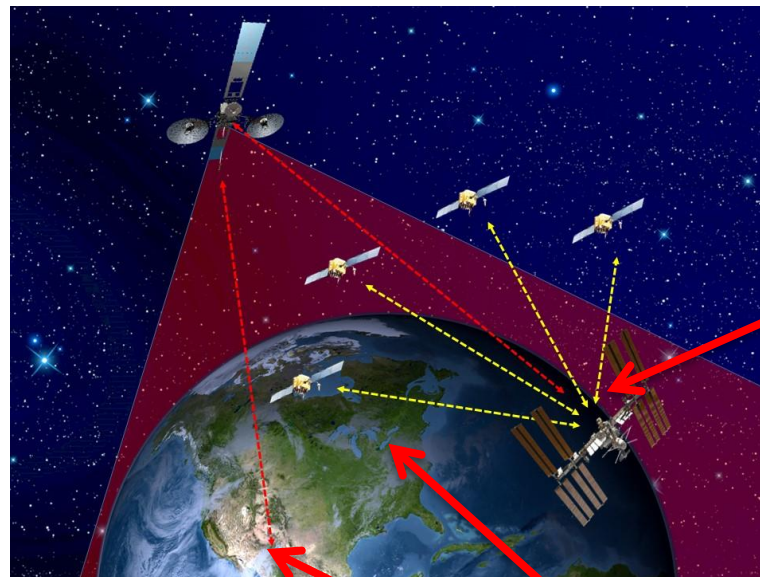
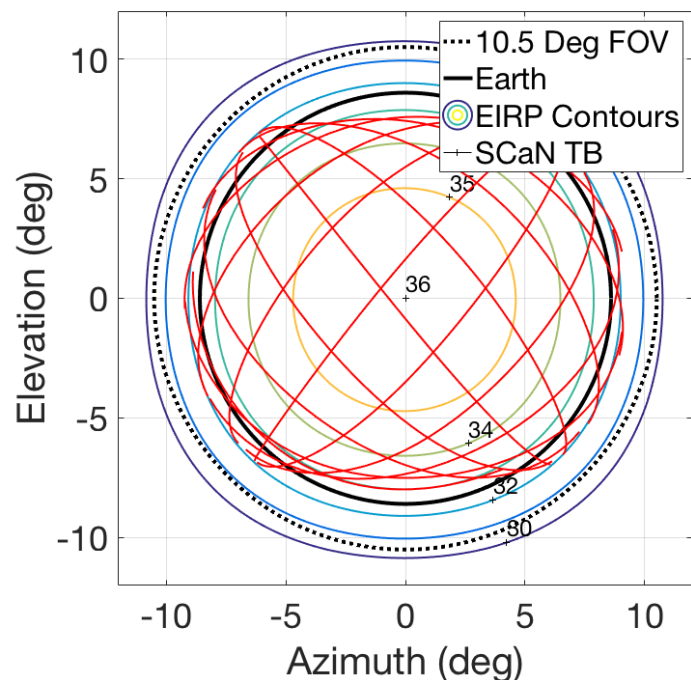


Coverage Analysis



	NGBS ² Configuration	3 ¹ Beacon	5 ¹ Beacon	3 ¹ Beacon	5 ¹ Beacon
Orbit	User ² Antenna ² Model	% ² Availability		Outage ² Duration ² (Minutes) ² 90% ² Bound	
ISS	GPM	98.46	99.80	0.45	0.45
ISS	-3 ¹ DBISO	100.00	100.00	0.00	0.00
ISS	MMS	99.97	99.97	0.00	0.00
ISS	LADEE	100.00	100.00	0.00	0.00
SSO ¹ LEO	GPM	92.16	97.94	0.67	0.45
SSO ¹ LEO	-3 ¹ DBISO	100.00	100.00	0.00	0.00
SSO ¹ LEO	MMS	100.00	100.00	0.00	0.00
SSO ¹ LEO	LADEE	100.00	100.00	0.00	0.00

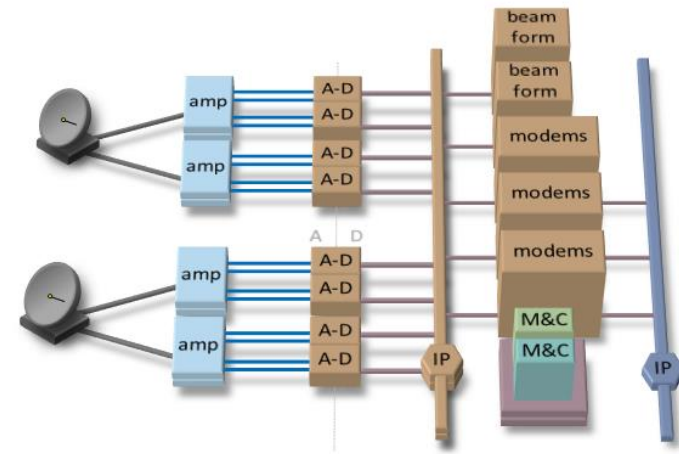
- Analysis incorporates 36 dBW peak EIRP, conservative user terminal G/T
- 3 TDRS constellation can provide global coverage with a 1024 bps data rate
- 1024 bps link is robust, 2048 has positive (slight) margin



SCaN TestBed
used to
validate EIRP
contours

- Objective 1: validate 4 element array beam pattern and peak EIRP
- Objective 2: quantify 2nd gen TDRS MAF EIRP margin

Ground measurements
taken at WSC & GRC



- [illegible]

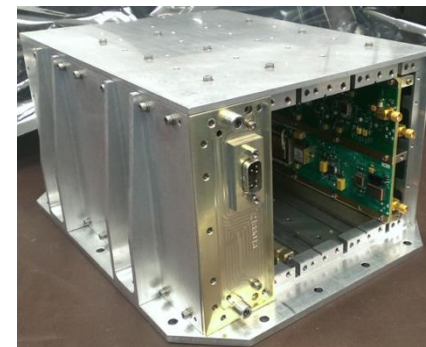
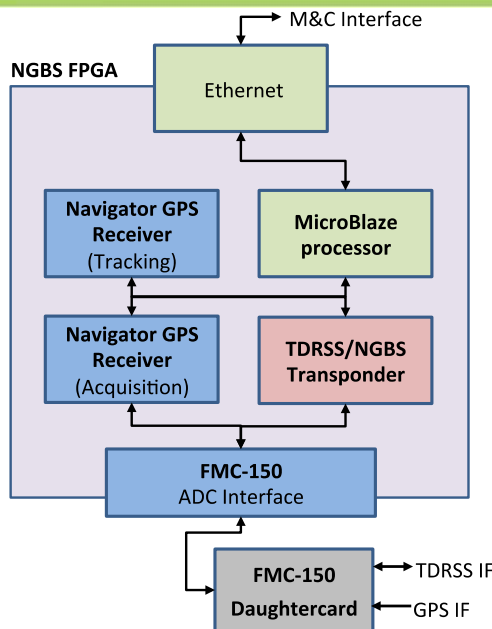
Real time data connection from JPL



User Element



ML605 breadboard development platform

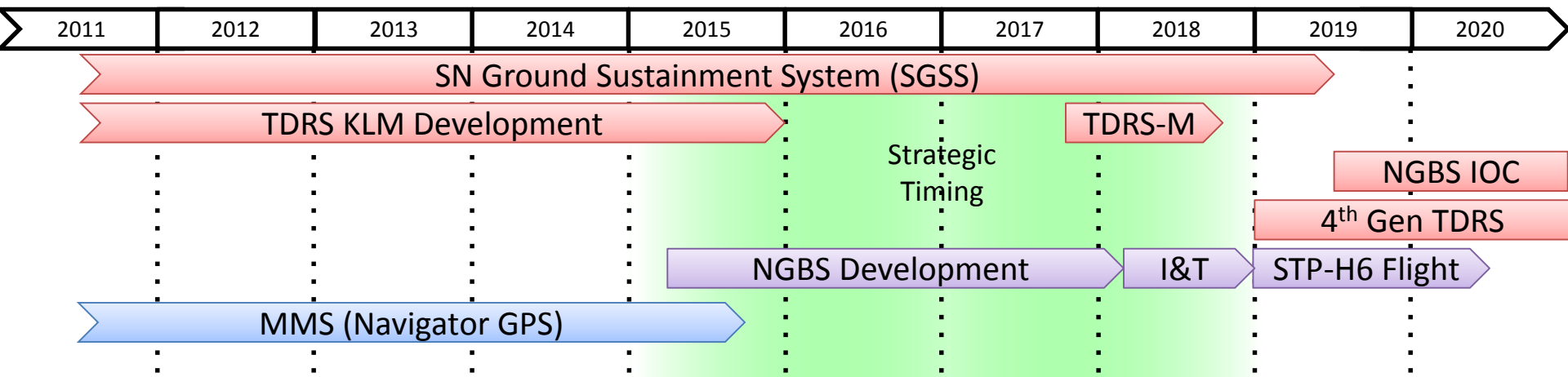


NavCube Engineering Test Unit with GPS + SpaceCube flight components

- NGBS terminal combines following mature technologies:
 - Navigator GPS
 - TDRSS transponder waveform
 - NGBS receiver waveform
 - Goddard Enhanced Onboard Navigation System (GEONS) flight software
 - SpaceCube 2.0 hardware
- STP-H6 provides a low-cost opportunity to flight qualify NGBS terminal
 - Launches in Dec 2018
- NGBS terminal intellectual property:
 - Deployable on lower SWAP hardware platform
 - Opportunity for smallsat/cubesat community



Potential for Initial Operational Capability



- Strategic opportunity exists:
 - Launch of TDRS-M in Oct 2017 will provide 6 NGBS capable spacecraft
 - SGSS necessary for NGBS ground implementation
 - STP-H6 provides a low cost opportunity to fly NGBS user element and demonstrate NGBS on orbit
 - NGBS user element is built on mature Navigator GPS receiver technology
- NGBS is a first step in advancing the next generation network paradigm as laid out in Space Mobile Network
 - Lessons learned from NGBS will inform beacon service on 4th gen TDRS



Closing Thoughts...



- NGBS:
 - With DAS, enables user-hailed services that are autonomously scheduled by the network
 - Provides spacecraft with radiometrics and data to support autonomous, on-board navigation and operations
 - Provides capabilities fundamental to the Space Mobile Network concept
- A fully operational beacon service will go beyond current implementation of NGBS:
 - Specifically designed service on “4th gen” TDRS could provide increased data rate and also a greater service volume
 - Earth based beacons could offer much higher EIRP for users in HEO or cis-Lunar space
- Engagement from the user community is key